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NATIONAL PHOTOGRAPHIC
INTERPRETATION CENTER

TEST AND EVALUATION REPORT

25X1

STEREO COMPARATOR TYPE 1740A

DECLASS REVIEW BY NIMA / DoD

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NPIC/R-30/72

SEPTEMBER 1972

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TECHNICAL PUBLICATION

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[redacted] STEREO COMPARATOR TYPE 1740A

September 1972

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[redacted]

Test and Evaluation Branch
Engineering Support Division
Technical Services Group
National Photographic Interpretation Center

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ABSTRACT

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The 1740A Stereo Comparator, made by the [redacted] has been tested for compliance to NPIC specifications. The Comparator is generally adequate for its purpose, although it does not comply in all details. In addition to acceptance tests, an engineering evaluation was made to determine certain other characteristics considered significant.

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Photogrammetrists were especially concerned with the joystick performance and with the reticle size. As a result of their evaluation, the joystick sensitivity was lowered so that it could control pointing motions. And, the original reticles were replaced with larger ones so that they could be seen more easily. A headrest was also added.

Off-axis resolving power and field of view were measured to be below the specified values. At the maximum magnification of 120 X (nominal), field curvature is noticeable. On-axis resolving power, with 1 X zoom, measures higher than that specified.

The 1740A Stereo Comparator is shown in Figure 1.

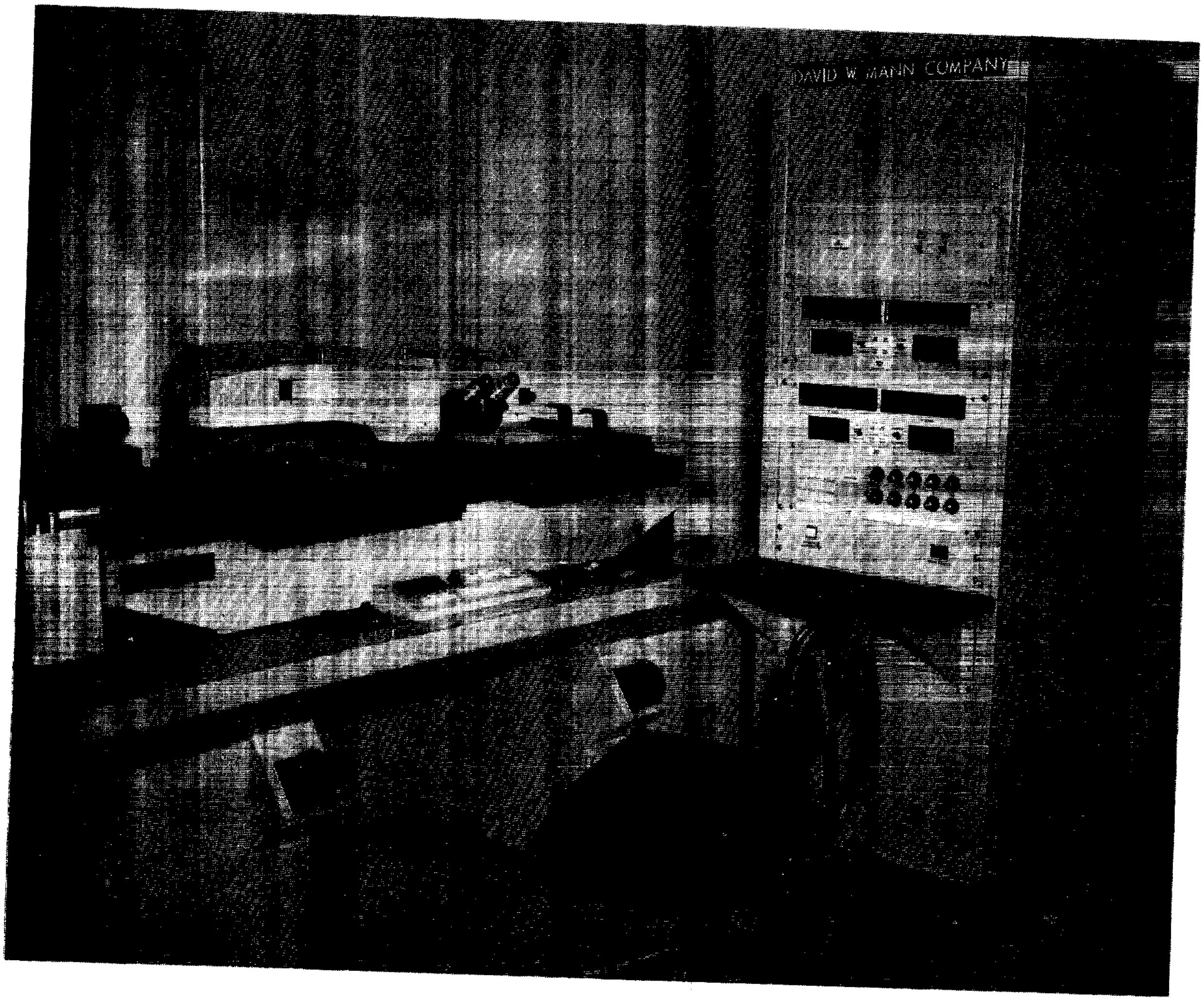

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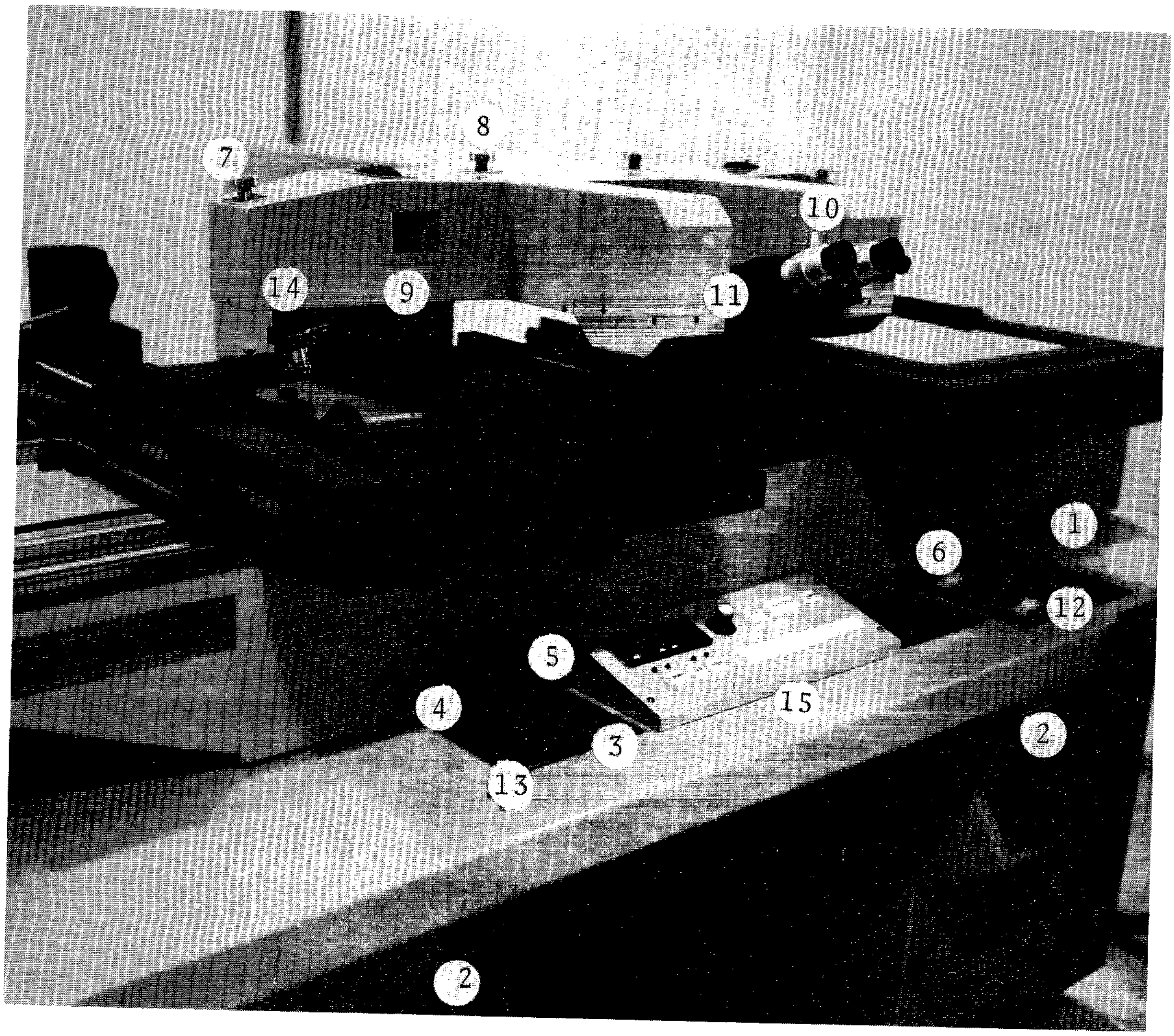
FIGURE 1. [redacted] Stereo Comparator (Type 1740A)



Controls Key:

1. Joystick
2. Handwheels
3. Illumination
4. Color Filters
5. Neutral Density Filters
6. Left-Both-Right Switch
7. Fine Focus
8. Zoom Ratio
9. Image Rotation
10. Interpupillary Distance
11. Eyepiece Tilt
12. Slew-Set Control
13. Substage Condenser
14. Objective Lens Turret
15. Remote Input Controls

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FIGURE 2. Stereo Comparator, Operator's Controls

1. INTRODUCTION

1.1 Background - The 1740A Stereo Comparator was developed by TSG/RED for the Photogrammetry Division (IEG/PHD). It is designed to precisely measure coordinates on large sizes of stereo film pairs.

25X1 [redacted] manufactured the Comparator according to RED specifications. Delivery to NPIC was on 16 August 1971. [redacted] engineers installed the Comparator
25X1 in Room 2N 816 in the Photogrammetry Division. The Test and Evaluation Branch (TSG/ESD/TEB) began acceptance testing during the last part of August 1971.

After a period of evaluation, representatives of PHD decided that larger reticles were needed and that the joystick had potential for controlling pointing motions. As a result of this evaluation, larger reticles were installed and the joystick sensitivity lowered. A headrest was also added. These changes were made during the last part of April 1972.

A separate Operational Suitability section is not included in this Test and Evaluation report since the operator's comments were few in number. However, the most important comments made by the operators are mentioned in appropriate paragraphs.

1.2 Test Objectives - Test plan objectives accomplished include, (1) testing Comparator characteristics for conformance to contract specifications, and (2) evaluating characteristics not specified but considered significant.

2. SUMMARY OF TEST RESULTS

2.1 Acceptance Tests - Acceptance testing was performed to determine whether the contract specifications were met. The following paragraphs discuss some of the most important characteristics tested. Detailed test data are listed in Section 5.

2.1.1 Image Quality - The resolving power on axis with the 1 X zoom, 10 X eyepieces, and 3 or 6 X objectives is satisfactory. Maximum resolving power on the left stage is 515 line pair/mm. On the right stage the maximum is 579 line pair/mm. The 2 X zoom degrades the resolving power to below specified values. Off-axis resolving power (at .8 of the field of view) is poor at all magnifications. This loss is probably caused by excessive curvature of field.

The optics are relatively free from astigmatism effects, chromatic aberrations, and geometric distortions. Subjectively, the field curvature is very apparent, especially at the highest magnification of 120 X.

On the average, at all combinations of magnification using the 10 X eyepieces, the field of view is about 11 percent low.

Subjectively, the light available at the eyepieces is more than enough, even with the density filters in the optical path.

2.1.2 Measurement Accuracy - At room temperatures the Comparator's errors are within, or very close to, specification limits of plus or minus 2 micrometers in 10 centimeters travel. Orthogonality errors are also within specification limits. Measurement errors referenced to 68 degrees F were found to be greater than specified. Room temperature variations exceeded the manufacturer's recommendations of 70 plus or minus 1 degree F. Therefore, accuracy and orthogonality measurements may be in error. The manufacturer also recommends laminar airflow and clean room conditions. Neither are provided as part of the Comparator's environment.

2.1.3 Reticles - The original 12 micrometer reticle dots were not large enough to be seen. Two other sizes have been tried. The last, a 30 micrometer dot, seems satisfactory to the photogrammetrists.

2.1.4 Stage Motion Control - The joystick, as originally installed, controlled stage speeds from less than 30 micrometers/second to greater than 5000 micrometers/second as specified. The joystick's speed range was changed so that it can be used for making pointing motions as well as for making slewing motions.

2.1.5 Film Stages - The platens can accept film from 1.5 to 7.0 mils in thickness. Good focus can be maintained over the entire measurable area of 255 X 255 mm.

2.2 Engineering Evaluation - Certain characteristics not specified were examined to further insure that the Comparator's design and construction were satisfactory.

2.2.1 Safety - No mechanical hazards were noted. Leakage current through the third conductor measured 9 ma through 1500 ohms resistance of a Simpson Leakage Current Meter. Installation of an isolation transformer has reduced this current to below the detection level of the meter.

2.2.2 Stage Motion - Continuing efforts are to be made to obtain a joystick system which will be suitable for control of pointing motion. The Comparator's controls do not include a rotatable joystick. Photogrammetrists want this feature so that the direction of stick displacement can be made to correspond to the apparent (with respect to the film) motion of the reticles. The stick rotation feature was not specified in the contract for the Comparator. The joystick rotation feature was not specified, but photogrammetrists believe it to be valuable.

The handwheels have play such that no stage motion occurs until the wheels have been rotated several degrees.

2.2.3 Reticles - Three reticle sizes have been tried, and the last, a 30 micrometer opaque dot, seems satisfactory to the photogrammetrists.

2.2.4 Human Factors - The anthropometric dimensions for eyepiece height and kneewell are satisfactory. Labels were omitted from the zoom control, IPD adjustment lever, and from the special character switches on the remote and main control panels.

And several photogrammetrists find the image rotation control hard to move.

2.2.5 Overall Construction - The overall construction of the Comparator is good. Parts have been well matched to give a pleasing appearance. Construction materials are of very good quality. Therefore, with proper oiling and cleaning, the Comparator should need very little other maintenance.

3. CONCLUSIONS AND RECOMMENDATION

The 1740A Stereo Comparator is a well designed instrument overall. Certain marginal characteristics were noted during testing which do not really restrict it from meeting the design purpose. Operational use of the 1740A is recommended.

4. DESCRIPTION OF EQUIPMENT

The 1740A Stereo Comparator is designed to make precise coordinate measurements on stereo film pairs. Two identical stages (left and right) hold the film flat, move it with respect to fixed reticles, and measure the x and y displacement components between points.

The photogrammetrist controls slewing motions of these stages by pressing on the pressure-sensitive joystick. For fine pointing he can use two handwheels, one for each direction of motion. The original joystick sensitivity has been lowered so that it can be used for pointing as well as slewing.

Each optical path lets the photogrammetrist choose magnifications from 7.8 X to 120 X by selecting various combinations of 6 or 10 X eyepieces, 1-2 X zoom ratio, and 1.3, 3, or 6 X objective lenses. Each path also provides 3 neutral density filters, 4 color temperature correcting filters, fine focus control, and continuous 360-degree image rotation.

The measuring system consists of lead screws with optical shaft encoders which count the screw revolutions. These rotational signals are processed by a data acquisition system to give measurements to 1 micrometer least count.

Console controls are easily reached by the operator. These consist of the following: joystick (1), handwheels (2), illumination (3), color filters (4), neutral density filters (5), left-both-right stage control (6), fine focus (7), zoom ratio (8), image rotation (9), interpupillary distance (10), eyepiece tilt (11), slew-set control (12), substage condenser (13), objective lens turret (14), and remote input controls (15). All these controls are identified by corresponding numbers on Figure 2.

Illumination in each optical path is provided by tungsten lamps. These lamps are placed toward the back of the operator's console and can be changed easily. General illumination, used to position film on the platens, is provided by cold cathode lamps placed under each bottom platen glass.

The data acquisition console contains all power supplies, main switches, measurement readout display, pre-set and reset readout switches, and computer interface circuitry. The arrangement of this console is identical to that of other NPIC data acquisition systems.

5. TEST DETAILS

5.1 Acceptance Tests - The Acceptance Test Details section describes the contract specification, test method, test results, and conclusion for each characteristic or quality listed in the contract.

5.1.1 Resolving Power Specification - Resolving power per magnification power requirements are as follows:

Field Position	Zoom Magnification (X)	Eyepiece Magnification (X)	Resolving Power (1p/mm/X)
On Axis	1.0	10	6.0
Off Axis (.8)	1.0	10	5.0
On Axis	2.0	10	5.0
Off Axis (.8)	2.0	10	4.5
On Axis	1-2	10	5.0
Off Axis (.8)	1-2	10	4.5
On Axis (Lmt.)	1-2	10 (6 X Obj.)	5.0 (600 1p/mm)

Test Method

Resolving power measurements, both on and off axis, were made according to test procedures described in the Optical Testing Procedures Manual. Film target, TEB #1, which is a medium contrast, 3-bar configuration target, was used. Comparator magnification up to the eyepieces was measured using Magnification Test #1, also in the Manual. The magnification power (standardized) of the eyepieces was measured using the reciprocal magnification technique, described in An Introduction to Optical Testing, by D. Sinclair. Measurements were made both in the tangential (T) and sagittal (S) pattern directions.

Test Results

TABLE 1. MAGNIFICATION MEASUREMENTS

Nominal System Magnification (X)	Measured System Magnification (X) Left Stage	Measured System Magnification (X) Right Stage
13.0	13.0	13.7
26.0	26.4	26.7
30.0	27.5	28.8
60.0	57.8	56.3
60.0	57.6	59.3
120.0	116.0	118.4

Measured Eyepiece Magnification (X)	
Left Stage	10.05
Right Stage	10.01

TABLE 2. ON/OFF AXIS RESOLVING POWER MEASUREMENTS LEFT STAGE (1p/mm)

Nom. Mag.	Observer 1 T	Observer 1 S	Observer 2 T	Observer 2 S	Observer 3 T	Observer 3 S	Median Value T	Median Value S	Specified Value*	Below Specified Value T	Below Specified Value S
On Axis											
30	205	205	205	205	162	182	205	205	165	no	no
** 60	229	229	258	258	205	205	229	229	289	yes	yes
60	459	459	459	459	325	325	459	459	346	no	no
**120	515	515	515	515	409	364	515	515	580	yes	yes
Off Axis- Left .8 FOV											
30	145	145	145	145	145	129	145	145	138	no	no
60	205	205	205	205	205	205	205	205	260	yes	yes
60	325	325	258	325	258	258	258	325	288	yes	no
120	364	459	409	409	289	364	364	409	522	yes	yes
Off Axis- Right .8 FOV											
30	115	115	115	115	91	102	115	115	138	yes	yes
60	129	182	115	162	115	145	115	162	260	yes	yes
60	258	258	182	258	182	205	182	258	288	yes	yes
120	409	459	409	364	289	289	409	364	522	yes	yes
Off Axis- Top .8 FOV											
30	102	115	91	115	81	91	91	115	138	yes	yes
60	162	182	162	205	91	162	162	182	260	yes	yes
60	229	258	229	289	205	229	229	258	288	yes	yes
120	364	409	364	409	325	364	364	409	522	yes	yes
Off Axis- Bottom .8 FOV											
30	115	102	115	115	115	129	115	115	138	yes	yes
60	182	229	205	229	162	229	182	229	260	yes	yes
60	258	289	289	325	205	258	258	289	288	yes	no
120	364	409	325	409	229	364	325	409	522	yes	yes

TABLE 2. CONTINUED
RIGHT STAGE (lp/mm)

Nom. Mag.	Observer 1 T	Observer 1 S	Observer 2 T	Observer 2 S	Observer 3 T	Observer 3 S	Median Value T	Median Value S	Specified Value*	Below Specified Value T	Below Specified Value S
On Axis											
30	229	182	229	205	229	182	229	182	173	no	no
60	258	205	289	258	258	205	258	205	281	yes	yes
60	515	409	459	409	364	364	459	409	357	no	no
120	579	515	579	515	515	515	579	515	592	yes	yes
Off Axis-	Left .8 FOV										
30	57	129	64	145	129	129	64	129	144	yes	yes
60	162	162	115	205	145	162	145	162	253	yes	yes
60	229	258	205	258	205	205	205	258	297	yes	yes
120	409	459	409	459	364	364	409	459	533	yes	yes
Off Axis-	Right .8FOV										
30	115	129	115	145	129	129	115	129	144	yes	yes
60	182	182	145	205	182	162	182	182	253	yes	yes
60	258	289	229	325	182	205	229	289	297	yes	?
120	364	459	409	459	364	364	364	459	533	yes	yes
Off Axis-	Top .8 FOV										
30	115	129	129	145	115	129	115	129	144	yes	yes
60	205	205	229	205	205	205	205	205	253	yes	yes
60	258	258	258	229	205	205	258	229	297	yes	yes
120	459	515	515	515	409	459	459	515	533	yes	?
Off Axis-	Bottom .8 FOV										
30	102	102	115	102	102	129	102	102	144	yes	yes
60	115	162	115	129	115	129	115	129	253	yes	yes
60	258	258	258	258	115	129	258	258	297	yes	yes
120	325	409	325	409	229	364	325	409	533	yes	yes

Conclusion

Resolving power of the Comparator is below specification at most magnifications using the 2 X zoom. On axis, with 1 X zoom, the resolving power is more than adequate. Off-axis performance is quite poor at .8 of the field of view, with 1 X or 2 X zoom.

* The Specified Value, in line pairs per mm, is calculated by multiplying the resolving power per magnification by the total measured magnification. (See Table 1.)

**The 2 X zoom is used to obtain the first 60 X magnification and the maximum magnification 120 X.

5.1.2 <u>Stage Displacement Accuracy Specification</u> - The actual stage position at any interval in its travel, in the measuring direction, shall not deviate from the position indicated by the digital readout system by more than plus or minus 2 micrometers per 100,000 micrometers, or by plus or minus 5 micrometers (maximum) at 255,000 micrometers. The measuring direction is with the stages traveling toward the operator (B to F) and to his right (L to R). Calibration is to be referenced to 68 degrees F. Recommended environmental temperature limits are 70 plus or minus 1 degree F.

<u>Test Method</u>

The Comparator's stage displacement accuracy was checked by measuring a calibrated scale, made of low temperature coefficient Cervit, with the Comparator. Corrections were made for changes in lead screw temperature from 68 degrees F. The coefficient of expansion listed by the manufacturer is 6.4 x 10 -6 per degree F.

During a calibration run (0-24 cm) the room temperature rose more than 2 degrees F. This rise exceeded the limit suggested by the manufacturer. The effect of the rise is to cause movement of the optics and ways for which no corrections can be made. The room temperature could not be controlled. Therefore, calibration runs were taken in short 15-minute intervals, during which the temperature difference, start to finish, was 2 degrees F or less.

Temperature of the screw could not be taken easily without possible screw damage. Instead, we measured the drive nut temperature. We assumed that the nut temperature was higher than the actual screw temperature, since it has smaller mass, less surface area, and is in friction contact with the screw. To compensate for the nut to screw temperature difference and for the apparent nonuniform temperature along the screw, the average of 6 temperatures per 5 cm interval was used in calculating the correction to the measured length. Temperatures were measured using an [redacted] instrument with thermistor probes.

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The Cervit scale length increases in length only .2 micrometer with a 9 degree F temperature change from 68 degrees F. Therefore, no temperature corrections were applied to the calibrated scale lengths. Room temperatures varied from 67 to 79 degrees F during the Comparator calibration runs.

Total Comparator error, accumulated from 0 to 24 cm, was obtained by adding all interval errors and allowing for linear error propagation.

Test Results

Test results are summarized in Figures 3, 4, 5, and 6, which follow. The difference between TEB's results and [redacted] 25X1 is probably due to the difference in methods of handling temperature effects. [redacted] held the Comparator at a 25X1 constant temperature for a long period of time and assumed that the screw was at that temperature. Within Room 2N 816, where the Comparator is located, precise temperature control was not possible.

The SD (Standard Deviation) shown on Figures 3, 4, 5, and 6 was computed from sample measurements, according to the formula $SD = (\text{sum } (X_i - \bar{X})^2/n-1)^{1/2}$, where n is the number of samples.

Conclusion

Both calibration methods, TEB's and [redacted] may be subject 25X1 to question. The important finding is that at room temperature, with no corrections made, the Comparator's errors are within, or very close to specification limits. Accuracy measurements may be adversely effected by room temperature variations.

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KEY: TEB Data Corrected to 68 Deg. F.

TEB Data at Room Temperatures

Data Corrected to 68 Deg. F.

Average Value ± One SD., Plus Propagated Error

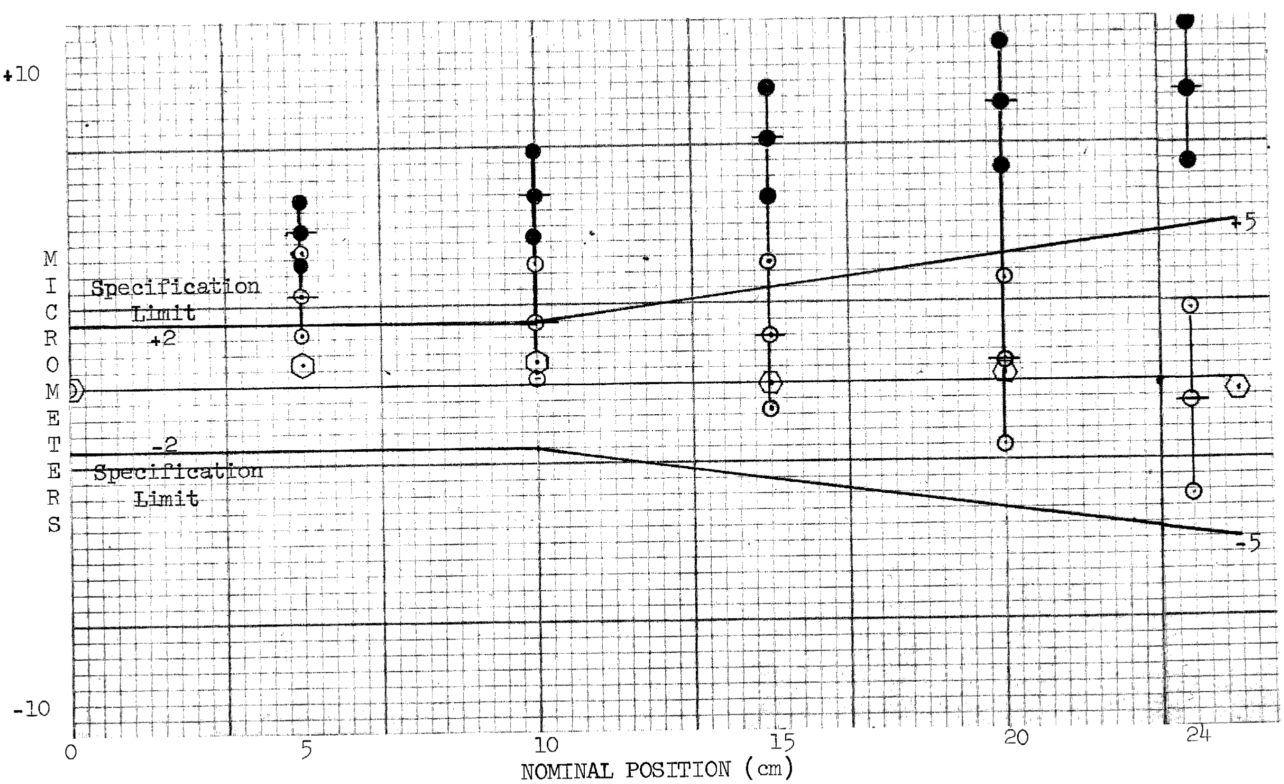

FIGURE 3. LEAD SCREW ERRORS/RIGHT STAGE--X AXIS (B to F)

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KEY: TEB Data Corrected to 68 Deg. F.

TEB Data at Room Temperatures

Data Corrected to 68 Deg. F.

Average Value ± One SD., Plus Propagated Error

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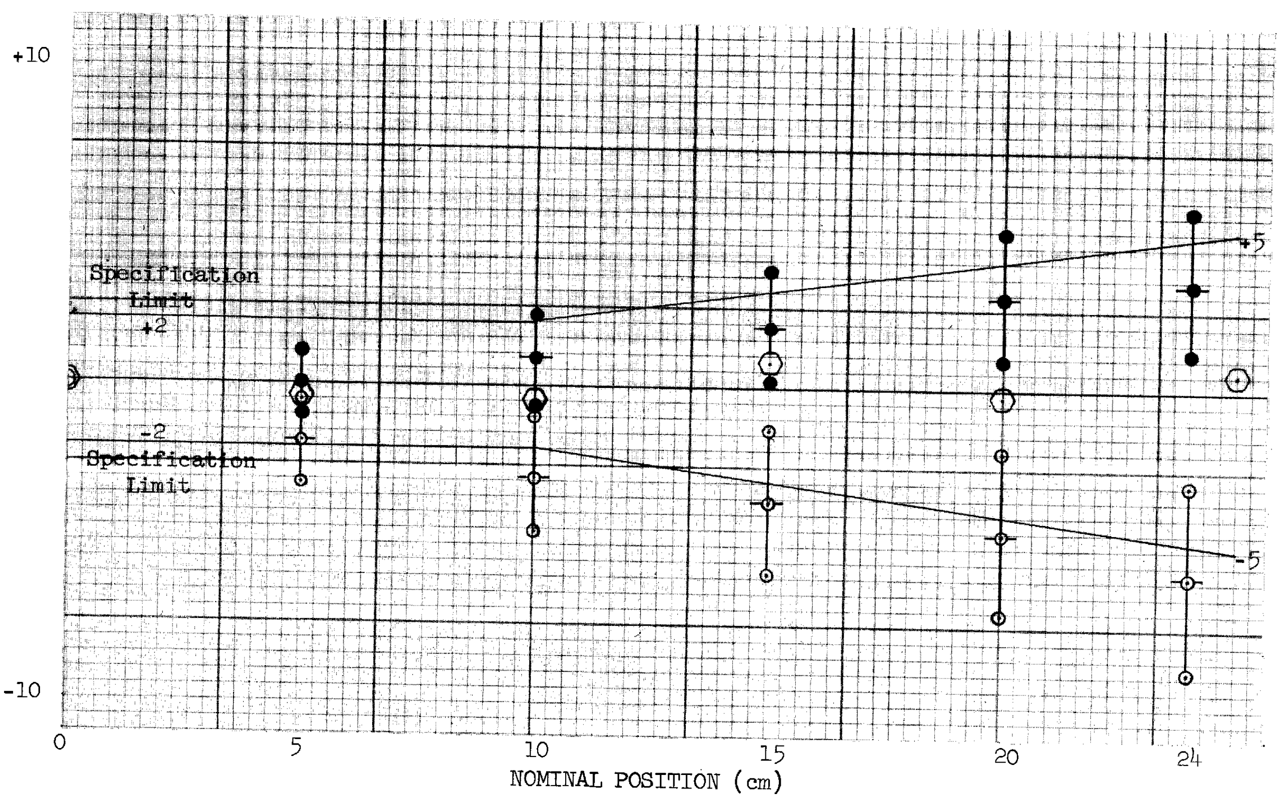

FIGURE 4. LEAD SCREW ERRORS/RIGHT STAGE--Y AXIS (L to R)

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KEY: TEB Data Corrected to 68 Deg. F. Data Corrected to 68 Deg. F.

TEB Data at Room Temperatures Average Value ± One SD., Plus Propagated Error

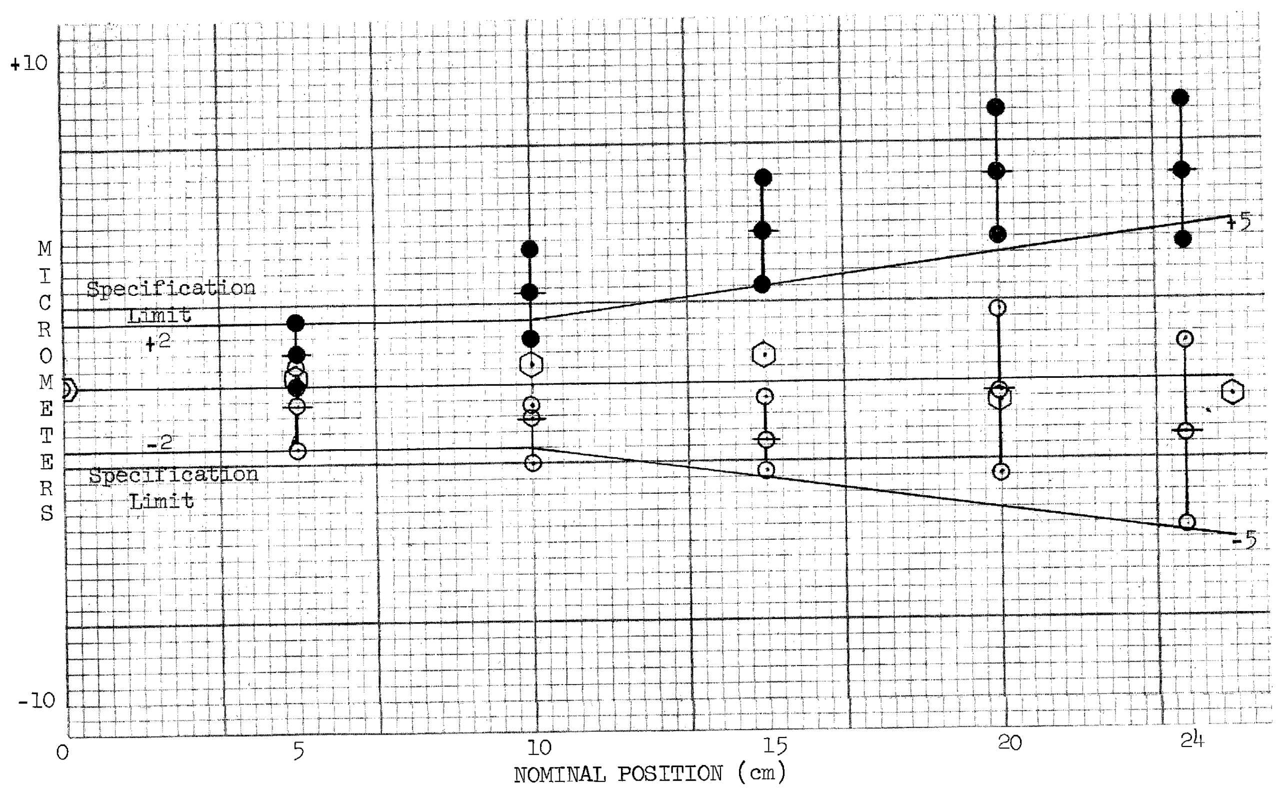

FIGURE 5. LEAD SCREW ERRORS/LEFT STAGE--X AXIS (B to F)

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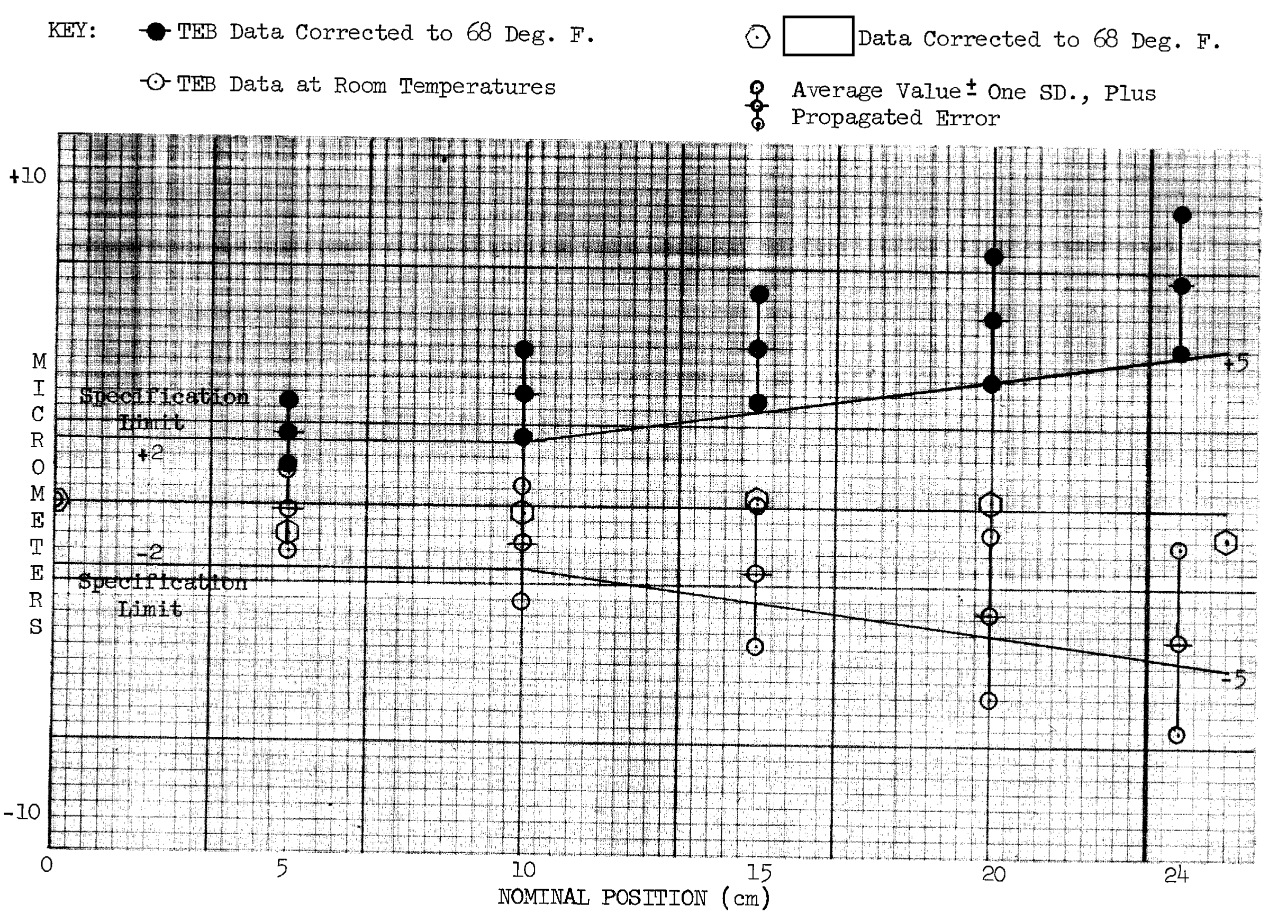

FIGURE 6. LEAD SCREW ERRORS/LEFT STAGE--Y AXIS (L to R)

5.1.3 Way Orthogonality Specification - The y-axis motions must be square with the x-axis motions to within plus or minus 3 seconds of arc.

Test Method

Orthogonality measurements for left and right stages were made using the diagonal scale method. Comparator measurements, x and y, of a calibrated linear scale, placed at nearly 45 degrees with one axis, give x and y values which when squared and summed should equal the scale length squared (Pythagorean Theorem). If the x and y axes are not perfectly square, the sum of x^2 and y^2 will be different from the scale length squared. The angular difference from 90 degrees is calculated as follows:

A (in radians) equals $1-(x^2/c^2 + y^2/c^2)$ all divided by $2xy/c^2$, where c is the calibrated scale length.

The x and y values in the formula are true lengths. However, since the Comparator has small linear errors, the x and y need correction. These corrections were made using linear calibration data for each axis. Thirty measurements were taken and the angle (A) calculated for each x,y pair.

Test Results

Averages of the 30 angular values are 1.1 and 3.0 seconds of arc for the left and right stages respectively. Standard deviations are 1.5 and 2.0 seconds of arc respectively. Table 3, which follows, shows the x and y values corrected for lead screw temperature and for linear accuracy. Accuracy of the test results may be adversely effected by room temperature variations.

Conclusion

The orthogonality of both stages is considered satisfactory.

TABLE 3

LEFT STAGE ORTHOGONALITY MEASUREMENTS (DIAGONAL SCALE METHOD)

TEMP. CORR. VALUES X (MICRO M.)	TEMP. CORR. VALUES Y (MICRO M.)	ACCUR. CORR. VALUES X (MICRO M.)	ACCUR. CORR. VALUES Y (MICRO M.)	ORTHOGONALITY ANGLE SECONDS OF ARC
166358.0	173007.5	166352.9	173005.0	0.1
166354.3	173008.9	166349.2	173006.4	2.7
166355.6	173010.1	166350.4	173007.6	-0.1
166352.0	173013.4	166346.8	173010.9	0.0
166351.0	173012.5	166345.9	173010.0	2.3
166348.4	173012.6	166343.2	173010.1	5.4
166351.0	173014.7	166345.8	173012.2	-0.3
166351.0	173013.5	166345.8	173011.0	1.1
166349.1	173014.3	166343.9	173011.8	2.4
166350.1	173014.3	166345.0	173011.8	1.3
166317.1	173042.9	166311.9	173040.4	4.2
166319.3	173044.1	166314.2	173041.6	0.0
166319.7	173043.4	166314.6	173040.9	0.5
166319.0	173043.7	166313.8	173041.2	1.1
166321.0	173043.7	166315.8	173041.1	-1.2
166319.9	173043.5	166314.7	173041.0	0.3
166320.3	173043.9	166315.2	173041.4	-0.6
166319.5	173043.2	166314.4	173040.6	1.2
166318.8	173042.4	166313.6	173039.9	3.1
166320.0	173042.6	166314.9	173040.1	1.4
166321.3	173043.9	166316.1	173041.4	-1.7
166320.6	173042.2	166315.5	173039.7	1.2
166320.9	173041.4	166315.7	173038.9	1.9
166321.2	173042.6	166316.0	173040.1	0.0
166322.4	173042.0	166317.3	173039.5	-0.7
166321.7	173041.2	166316.5	173038.7	1.2
166321.7	173041.3	166316.6	173038.8	1.1
166320.9	173040.4	166315.8	173037.9	3.1
166322.0	173040.6	166316.9	173038.1	1.6
166322.1	173040.8	166317.0	173038.2	1.3

MEAN VALUE OF ORTHOGONALITY ANGLE = 1.1

STANDARD DEVIATION OF ANGLE = 1.5

TABLE 3 - CONTINUED

RIGHT STAGE ORTHOGONALITY MEASUREMENTS (DIAGONAL SCALE METHOD)

TEMP. CORR. VALUES		ACCUR. CORR. VALUES		ORTHOGONALITY ANGLE
X (MICRO M.)	Y	X (MICRO M.)	Y	SECONDS OF ARC
173016.0	166351.1	173009.3	166348.5	-0.1
173013.3	166350.2	173006.6	166347.7	4.3
173016.7	166350.3	173010.0	166347.8	-0.1
173016.8	166346.4	173010.1	166343.9	4.5
173013.8	166348.5	173007.1	166345.9	5.8
173015.7	166346.5	173009.0	166343.9	5.8
173015.3	166348.3	173008.6	166345.7	4.2
173015.3	166350.3	173008.6	166347.8	1.8
173015.2	166348.5	173008.5	166345.9	4.1
173016.1	166349.4	173009.4	166346.9	1.9
173016.1	166350.5	173009.3	166347.9	0.7
172991.2	166377.2	172984.4	166374.6	-1.6
172989.6	166376.6	172982.8	166374.0	1.2
172989.1	166377.0	172982.3	166374.5	1.3
172986.4	166376.4	172979.7	166373.9	5.4
172989.8	166375.8	172983.0	166373.2	1.9
172990.1	166376.1	172983.3	166373.5	1.3
172986.2	166375.3	172979.5	166372.7	7.0
172986.7	166376.7	172979.9	166374.1	4.8
172987.9	166377.0	172981.2	166374.5	2.8
172987.8	166376.8	172981.0	166374.2	3.4
172988.0	166376.9	172981.3	166374.4	3.0
172987.2	166377.2	172980.5	166374.6	3.7
172988.5	166376.6	172981.8	166374.1	2.7
172988.8	166376.8	172982.0	166374.3	2.2
172987.0	166376.1	172980.3	166373.5	5.2
172987.2	166376.2	172980.5	166373.7	4.9
172989.4	166376.5	172982.7	166373.9	1.9
172988.6	166376.7	172981.9	166374.1	2.7
172989.9	166376.0	172983.1	166373.5	1.8

MEAN VALUE OF ORTHOGONALITY ANGLE = 3.0

STANDARD DEVIATION OF ANGLE = 2.0

5.1.4 Field of View Specification - The minimum field of view must be 20.0 mm divided by the objective magnification and zoom ratio (measured with the 10 X eyepieces).

Test Method

The field of view at the respective objective, zoom, and eyepiece magnifications was measured using the Comparator as the measuring device. A scale division mark was aligned with each edge of the FOV, and the displacement between taken as the FOV. Measured system magnifications were used in calculating the FOV specified at each combination of lenses. An average of four measurements is reported.

Test Results

TABLE 4. FIELD OF VIEW MEASUREMENTS/SPECIFICATIONS

Left Stage (micrometers)			Nominal Magnification	Right Stage (micrometers)		
Ave. FOV	Spec. FOV	% Low		Ave. FOV	Spec. FOV	% Low
13667	15504	11.8	13	13082	14599	10.4
6634	7605	12.7	26	6624	7491	11.6
6412	7299	12.2	30	6302	6944	9.2
3100	3350	7.5	60	3159	3559	11.2
3092	3490	11.4	60	3014	3367	10.5
1508	1733	12.9	120	1504	1691	11.1
	Ave	11.4			Ave	10.7

Conclusion

The FOV at all combinations of objectives and zoom lenses, with the 10 X eyepieces, is below specification values.

5.1.5 Aberrations Specification - The field of view will appear to be flat. The viewing system will have no apparent chromatic aberration, nor geometric distortion, nor astigmatism. The optical system will introduce no color into the viewed image (i.e., a white image will appear white).

Test Method

Flatness of field, chromatic aberration, distortion, and astigmatism effects were evaluated subjectively by looking at resolution targets and grids through the Comparator's optics. Observations were made at all combinations of system magnification.

Test Results

The Comparator has some apparent field curvature which occurs at approximately .8 of the FOV from the center. The loss in off-axis resolving power (see Table 2) is further evidence of the field curvature.

Some chromatic aberration is present in the optical system, especially at highest magnification, as evidenced by slight color fringes around the bars of the resolution target.

A grid with several lines presented to the FOV appeared to be very straight, showing that no significant distortion is introduced by the optics.

A small amount of astigmatism is present off axis at the highest system magnification.

Conclusion

With the exception of the curvature of field, the Comparator's aberrations are not excessive.

5.1.6 Light Condenser Specification - Two separate illumination systems, one for each leg of the stereo viewing system, are provided. The bulbs use tungsten filaments. Each source is matched to the maximum numerical aperture of the stereo observing system to optimize resolution.

Test Method

Resolving power measurements were made to determine the effectiveness of the match between the light source (condenser) and the objective lenses.

Test Results

On-axis resolving power of the Comparator, with both 3 X and 6 X objectives, and 1 X zoom, is more than satisfactory. Resolving power on axis, with the 2 X zoom, is somewhat low. Off-axis resolving power is low at all Comparator magnifications.

Conclusion

The light sources are probably well matched to the objectives, as shown by the good on-axis resolving power measurements. The loss in off-axis resolving power is probably due to the poor flatness of field. The 1-2 X zoom system is probably poor at the high end, as shown by the below-specification resolution readings at high magnifications.

5.1.7 Illumination Level Specification - The illumination level in the field of view at maximum light source intensity should not be less than 10 apparent foot lamberts (fL) when viewed at any magnification through a background density of 1.0.

Test Method

Apparent fL (not defined scientifically) measurements were made at each eyepiece (Left and Right), with both 6 X and 10 X eyepieces. Measurements were made at various (not all) combinations of objectives, zoom, and eyepieces. The light sources were set a maximum voltage. Readout in apparent fL was provided by the Gamma Model 2020 Photometer, calibrated at 100 fL with a Standard Light Source. A small pin hole attachment covered the fiber optics probe to insure that the probe tip was completely filled by the exit pupil of the Comparator. The Comparator was focused on the bottom platen and the neutral density filter, nominal value 1.0, placed in the optical path.

Test Results

TABLE 5. ILLUMINATION LEVELS

System Magnification (X)	Illumination (Apparent fL) Left Path	Right Path
7.8	320	--
15.6	365	--
18.0	600	390
36.0	630	690
36.0	1680	--
72.0	1500	--
13.0	1860	3780
26.0	1260	2460
30.0	--	750
60.0	--	--
60.0	1230	1020
120.0	695	780

Conclusion

A subjective evaluation confirms that the illumination available at the eyepieces is more than enough. A 7% transmission loss, due to the top platens, does not decrease the illumination level significantly.

5.1.8 Reticles Specification - One replaceable reticle shall be supplied in each leg of the viewing system. One set of reticles will have a 30 micrometer opaque dot in the center and a second set will have a 24 micrometer opaque dot (high contrast) in the center and a low contrast (0.18 D) circle surrounding it. The nominal circle diameter is to be 1800 micrometers, with a line width of 24 micrometers. These dots will be centered on the optical axis of the system.

Test Method

The effective diameter of the reticles and the line width (at the film plane) were measured using the Comparator as the measuring device. The effective diameter is the physical diameter reduced by a factor equal to the objective lens magnification power (i.e., with 3 X objective, a physical reticle diameter of 30 micrometers measures 10 micrometers).

A razor blade, with a high contrast and sharp edge was placed on the stage and the edge aligned with one edge of the reticle. The stage was then displaced until the other edge of the reticle was aligned.

Averages of two diameter measurements, taken both horizontally (left to right with respect to the field of view) and vertically, are reported.

The centering error of the reticles (from the field of view center) was measured in a similar way. We assumed that the optical axis was approximately at the field of view center.

The size and centering of the 30 micrometer reticle was not measured because a subjective evaluation indicated satisfactory performance.

Test Results

Reticle Dimensions (actual)	Left (micrometers)	Right
Dot	20.4	21.0
Circle (OD)	1950	1922
Circle (ID)	1917	1971
Circle (line width)	33	21
Centering Errors (referenced to film plane)		
Y axis direction	11	34
X axis direction	39	38

Conclusion

The dimensions of the 24 micrometer reticle are not exactly those specified. However, several photogrammetrists concluded that it was too small to be seen easily anyway. They generally concluded that the 30 micrometer reticle was satisfactory. The 24 micrometer reticle is not centered well, but this can be adjusted.

5.1.9 Least Count/Backlash Compensation Specifications - The [redacted] Type H 1045 reading heads, geared from the lead screws through backlash compensation devices, must provide a stage motion least count capability of 1 micrometer.

25X1

Test Method

The backlash in the x and y directions of both stages was measured by using the Comparator to point at fixed marks from opposite directions and noting the difference in positions. A backlash error of under 30 micrometers is considered to be compensated. Stage motion was controlled with handwheels.

Test Results

TABLE 6. BACKLASH ERRORS

Left Stage (micrometers)		Approach Direction	Right Stage (micrometers)	
		X Axis		
10003	20001	L-R	10003	20004
9991	19992	R-L	9990	19991
12	9	Error	13	13
9990	20011	L-R	9998	19988
10000	19998	R-L	10002	20001
10	13	Error	14	13
	11.0	Average Error	13.2	
		Y Axis		
10005	20003	L-R	9995	19994
10000	20002	R-L	9992	19989
5	1	Error	3	5
10003	20001	L-R	9999	19995
10002	20002	R-L	10005	20000
1	1	Error	6	5
	2.0	Average Error	4.8	

Conclusion

Backlash errors are within acceptable limits. The least count is one micrometer.

5.1.10 Film Gate Temperature Rise Specification - The film gate temperature rise due to the high intensity system must not exceed 4 degrees F above room ambient temperature over an 8-hour period. The illumination will be set at maximum and a 2.0 density film placed in the film gate.

Test Method

The film gate temperature rise was measured using a Simpson Therm-O-Meter with an iron-constantan ribbon probe. A film of density 2.0 was placed between the platen and the ribbon probe placed over the film. A second ribbon probe measured room temperature. The stage was positioned so that the film probe was directly over the light source. Only the right stage was measured.

Test Results

After approximately 4 hours the temperature of the film was only 1 degree above room temperature. We assumed that beyond 4 hours the film temperature would not change significantly. Film temperature measurements were not made beyond 4 hours because the room temperature increased more than 4 degrees from the starting temperature.

TABLE 7. FILM/ROOM TEMPERATURES

Film (Deg. F)	Time (Min.)	Room (Deg. F)
78.0	0.0	77.5
79.0	15.0	78.0
80.5	30.0	78.5
80.5	60.0	79.5
81.0	75.0	79.5
80.0	90.0	79.0
80.5	105.0	79.5
81.0	120.0	80.0
82.0	135.0	80.0
82.0	150.0	80.5
82.0	165.0	81.5
82.0	180.0	81.5
82.5	195.0	81.5
82.5	210.0	82.0
82.5	225.0	82.0
83.5	240.0	83.0

Conclusion

The Comparator's light sources do not heat the film excessively.

5.1.11 Film Thickness Specification - The platens must accept cut film from 1.5 to 7.0 mils in thickness.

Test Method

A subjective test was made by separately inserting two films, of respective thickness 1.5 and 7.0 mils, between the glasss platens. The focus capability of the Comparator was noted, using maximum (120 X) and minimum (7.8 X) magnifications, at several random points over the format.

Test Results

On both left and right stages the platens hold the films very flat and the Comparator can be properly focused (with emulsion toward objectives). Good focus can be maintained over the entire format.

Conclusion

The Comparator's focus capabilities are satisfactory for handling films from 1.5 to 7.0 mils in thickness.

5.1.12 Measurable Area Specification - The openings through the stages must permit a measurable area of 255 X 255 mm or 65025.0 mm^2.

Test Method

The stage aperture was measured using the Comparator as the measuring device.

Test Results

The left stage measures 65362.8 mm^2 and the right stage 65174.2 mm^2.

Conclusion

Both stage apertures are slightly larger than specified.

5.1.13 Stage Displacement Specification - Each stage assembly must have a measurement capacity of 255 mm direct to one micrometer.

Test Method

Stage displacements in both x and y directions, for each stage, were measured using the Comparator as the readout device. The stage motion was controlled using only the joy-stick.

Test Results

Averages of 5 stage displacements for the left stage are 256,124 micrometers and 255,200 micrometers in the x and y directions respectively. And the right stage measures 255,482 micrometers and 255,103 micrometers in the x and y directions respectively.

Conclusion

The Comparator's stage displacement distances are more than satisfactory.

5.1.14 Format Size Specification - The Comparator must accept cut film in sizes up to 10 X 10 inches.

Test Method

Format size of the stages was measured using a machinst's ruler.

Conclusion

Both left and right formats measure 11 X 11 inches, and thus are more than satisfactory.

5.1.15 Neutral Density/Color Temperature Correction Filter Specification - Two pairs of four position filter wheels must be provided, one pair for each illumination leg. These wheels are to be remotely indexable by the operator and are to carry the selected filters. Neutral filter densities will be 0.5, 1.0, and 1.5. For color work, color temperature correcting filters will be inserted via the second wheel in either side. The "mired" (micro-reciprocal degree) values will be selected from the Kodak number 78 and 86 Series Wratten Photometric Filters.

Test Method

Neutral density filters were measured using a Gamma Model 2020 Photometer, with photopic filter. Illumination measurements, made at the eyepieces, were taken first without the N.D. filters and then with them. Each density is computed as the log 1/T, where T is the ratio of the illumination with filters to the illumination without filters. As no specific values were specified for the color temperature filters, no measurements were made.

Test Results

Filter densities of the left stage were .56, .94, and 1.43. On the right stage densities were .56, .93, and 1.41.

Conclusion

The neutral density filters are satisfactory as the measured values are within about 10% of the nominal values.

5.1.16 Stage Coordination Specification - The stages during slewing must stay together to within the field of view of the observing system at the maximum design magnification (120 X).

Test Method

Stage coordination measurements were made by displacing the left stage an amount equal to the field of view. The amount of displacement of the right stage was then noted and the ratio of right displacement/left displacement computed. A ratio close to 1.00 indicates satisfactory performance. Coordination ratios were computed for x and y displacements, with motion controlled by both handwheel and joystick controls.

Test Results

Averages of 2 measurements are 1.03 and 1.02 in the x and y axes respectively, with stage motion controlled by handwheels. With the joystick control, ratios of 1.03 and 1.01 are given by the respective x and y axes.

Conclusion

As the coordination ratios are very nearly 1.00, the performance is adequate.

5.1.17 Screw Lead/Pitch Specification - The precision lead screws of the longitudinal and cross slides must have a pitch of 1 mm and a lead of 2 mm, thus providing a 2 mm motion of the stage with 1 revolution of the screw. The screws are to be precision cut and lapped for accuracy and are to be mounted in super precision ball bearings.

Test Method

Measurements of stage displacement accuracy, orthogonality of the x and y stages, and velocity were considered enough to show the characteristics of the lead screws. A direct measurement of lead and pitch might cause damage to the screws.

Test Results/Conclusion

Stage velocity requirements of from .03 mm to 5 mm per second are more than met. The accuracy and orthogonality of the stages are considered to be within specification limits. Therefore, the lead and pitch of the screws is also considered satisfactory.

5.1.18 Power Consumption Specification - The power requirements for the entire system is 115 volts, 10 amperes, of 60 cycle, single-phase current.

Test Method

The power consumption of the Comparator and Data Acquisition System was measured with a Simpson Volt-Amp-Watt meter. Input voltage of 117 volts was controlled by a General Radio, Type 1592, Voltage Regulator. All controls and lights were set at maximum so that maximum current was drawn.

Test Results/Conclusion

Maximum power consumption is 670 watts, at 117 volts and 6.4 amperes, which is well below the maximum power specified.

5.1.19 Power Drive Speed Specification - Provision must be made for continuously variable power drive speeds from approximately 30 micrometers per second to 5000 micrometers per second for each set of x-y screws. Switches permit power drive slewing of the left or right stages independently or simultaneously at approximately the same speeds.

Test Method

Individual stage displacement distances were measured using the Comparator as the readout device. The time duration of the displacement was measured using a stopwatch which was started and stopped electrically. For each axis and for each stage the joystick displacement was fixed at an angular position to give approximately the speeds specified. Both the stage motion and the stopwatch were started and stopped simultaneously.

Test Results

TABLE 8. POWER DRIVE SPEEDS

Speeds
(micrometers/sec.)

Left Stage		X-Axis	Right Stage		
t(sec.)	Displacement	Speeds	t(sec.)	Displacement	Speeds
15	214	14	15	217	15
15	196	13	15	199	13
60	360	6	60	363	6
60	3886	65	60	3888	65
30	202642	6755	30	206160	6872
30	203181	6773	30	208644	6955
		Y-Axis			
30	215997	7200	30	207923	6931
30	214540	7151	30	205810	6860

(Slower speeds were obtained but were not measured.)

Conclusion

The range of power drive speeds is more than adequate. Speeds slower than 10 micrometers per second were obtained.

5.2 Engineering Evaluation - The Engineering Evaluation section contains evaluations made on characteristics not uniquely specified in the contract.

5.2.1 Safety - The Comparator was examined by TEB and by
25X1 the [redacted] for mechanical hazards which might cause possible harm to the operator. None were noted.

Leakage current (through the 3rd conductor) measured 9 ma through 1500 ohms resistance of a Simpson Leakage Current Tester. This exceeds the American National Standard for Leakage Current for Appliances of .75 ma. After installation of an isolation transformer the leakage current could not even be detected.

5.2.2 Joystick - The original purpose of the joystick was to control slewing motion. The Comparator's pressure-sensitive stick performed so well that an attempt was made to decrease the sensitivity further so that it could be used for pointing. After the first modification the minimum speed was still too high. A second modification decreased the speed to allow precise pointings. However, excessive pressure must be applied to the stick to give even the slowest speeds.

Continuing efforts are to be made to obtain a displacement-sensitive stick similar to that on the Point Transfer Device. This stick rotates so that the direction of stick displacement corresponds to the apparent (with respect to the film) movement direction of the reticle.

5.2.3 Handwheels - The handwheels have play such that no stage movement occurs until the wheels have been rotated several degrees. This play does not cause measurement inaccuracies, but gives non-positive control of stage motion.

5.2.4 Platen-Objective Interference - On both stages when the turret is rotated the 1.3 X objective lens bumps the platen frame. This occurs when the stages are at or near the limit of travel. On the left stage the 1.3 X objective can contact the platen lifting lever mount.

5.2.5 Reticles - Three reticle sizes have been tried in the Comparator. The first was an opaque dot 12 micrometers in diameter (actual size, not size effective in the film plane). With 10 X eyepieces the dot was hard to find and even more difficult to keep. A 24-micrometer diameter dot, with a surrounding circle of 1800 micrometers, was somewhat more visable, but was not satisfactory to most operators for stereo pointing. The third reticle, presently in use, is a 30-micrometer dot. This larger size has enabled the operators to easily locate the reticle dot within the image.

5.2.6 Human Factors - The anthropometric dimensions for eyepiece height and kneewell are satisfactory.

Labels were omitted from the zoom control, IPD adjustment lever, and from the special character switches on the remote and main control panels.

No storage area was provided for cleaning materials, eyepieces, manuals, and extra lamps.

Several photogrammetrists find the image rotation control hard to move.

5.2.7 Overall Construction - The overall construction of the Comparator is good. Parts have been well matched to give a pleasing appearance. Construction materials are of very good quality.

The maximum dimensions of the Comparator's console are 68 inches (wide), by 44 inches (high), by 42 inches (deep). The Data Acquisition rack measures 22-3/8 inches (wide), by 71-3/4 inches (high), by 25-1/2 inches (deep). Height measurements were taken from the floor.

The Comparator has been well made and should, with proper oiling and cleaning, need very little other maintenance.

Tungsten filament lamps, which provide illumination for each optical path, are located toward the rear of the operator's console. These lamps can be replaced easily.

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